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Exploring on farm climate change adaptation strategies - April 2018

The Impact of Climatic Change Adaptation on Agricultural Productivity in Central Chile: A Stochastic Production Frontier Approach

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1. Background – Agriculture and Productivity

CC and variability

- Farmers modify their practices to cope with climatic variability since centuries
- CC threatens their life forms due to the increasing, unpredictable, frequent and intense occurrence of extreme meteorological events such as droughts, floods and frosts (Clements et al 2011)

Productivity

- Important issue in economics, a determinant of welfare
- Special place in Ag Econ given the dependence on natural resources
- Concern about the idea that we are going beyond the limits of natural capital available for food production (Fuglie & Schimmelpfennig 2010)

CC: Climate Change

1. Background – CCA in Agriculture

Adaptation (Zilberman et al 2012)	Response of economic agents and societies to major shocks, such as CC
	Adaptation practices are adjustments to improve resilience or reduce vulnerability to changes in climate observed or expected (IPCC 2007; 2014)
CCA is imperative for 3 reasons (Nelson et al 2007)	1. Many future environmental risks are now more apparent and predictable
	2. Although the risks are not quantifiable, the environmental changes are significant
	3. Environmental change, although it is the product of many factors, has indisputable human causes
Changes in food production will affect consumers, but producers are who take the adaptation decision and who assume the costs of efficiency improvement (AGRIMED 2008)	Many studies have investigated the factors associated with agricultural productivity in the world, however, the literature linking efficiency with CCA is scanty

CCA: Climate Change Adaptation

1. Background – CC in Chile

Background

- IPCC models: reduction of rainfall and increase of temperatures under scenarios of increase of GHG (Falvey & Garreaud 2007; 2009)
- Displacement of actual agricultural areas to the south (AGRIMED 2008)
- Rainfall reduction observed during the last 50 yeas (10%) will continue for the next 50 years (Andersen & Verner 2010)

Documented effects

- Reduction of water resources (Maipo) (Meza et al 2012)
- Changes in vines phenology (Jorquera-Fontena 2012)
- Reduction of future yields of maize and wheat (10-30%) (Meza & Silva 2009; Meza et al 2008)

Agriculture & forestry sector

- 18% of exportations
- 11% of employment
- National Plan for Adaptation (2013)
- Mitigation and adaptation commitments derived of international agreements

2. Research Questions & Objective

Research questions

- Is it possible to include the CCA in a production function?
- Is there evidence of an increase in productivity of the farmers most adapted to the CC?
- Are there differences depending on the CCA strategy used?

The objective is to investigate whether adaptation practices can increase productivity in the agricultural systems of annual crops of Central Chile

3. Data & Methods – Study Area

The study area covers 8,958 farms in 4 municipalities of the Maule Region, in Central Chile, a Mediterranean transition zone between the arid north and the rainy south

Projections for the study area comprise a decrease in precipitation of up to 40% and a rise in temperatures between 2 °C and 4 °C in the next 40 years

This region is a major contributor to the agricultural output of the country and, despite rapid technological progress in recent years, the cultivation of annual crops, fruits and vegetables is not changing fast enough to counteract the predicted adverse effects of climate change (FIA 2010)

Specific adverse effects expected in the near future concern losses in the quality of the environment for agricultural production (Hannah et al 2013)

3. Data & Methods – Survey

- The data come from a survey applied to a random sample of producers, 274 interviews were performed, representing little more than 3% of the producers in the study area. The survey was targeted at annual crop producers

- Surveys with missing information were excluded from the analysis, leaving 265 valid observations

TALCA

Folio	

ENCUESTA A PRODUCTORES

"Impactos y estrategias de adaptación al cambio climático de diferentes sistemas agrícolas de la zona central de Chile".

Nota: Toda la información proporcionada con objeto de la presente encuesta será confidencial. El manejo de los datos será sólo de tipo estadístico y NO serán facilitados a terceros. La información personal solicitada tiene por único fin verificar el proceso de recolección de información y dirimir posibles dudas posteriores respecto de algunas preguntas no contestadas por error u omisión del encuestador.

IDENTIFICACIÓN	Código Encuestador		
Encuestador	Fecha		Firma

DIGITACIÓN	Nombre Codificador		
	Fecha		Firma

Información preliminar

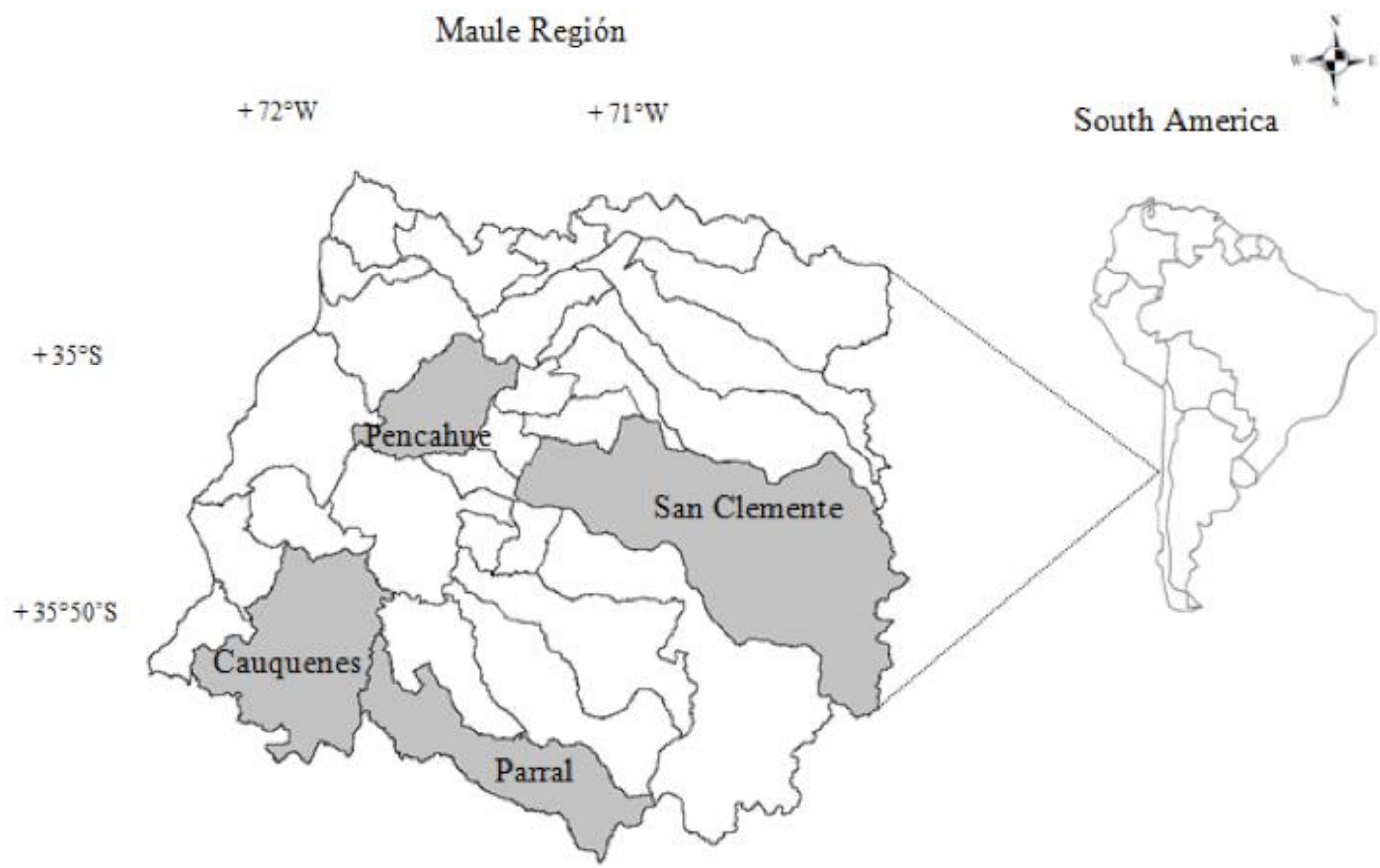
Comuna	Sector
Coordenada X	Coordenada Y
Nombre productor	
Comunidad de Agua (San Clemente y Parral)	
Teléfono	e-mail

1

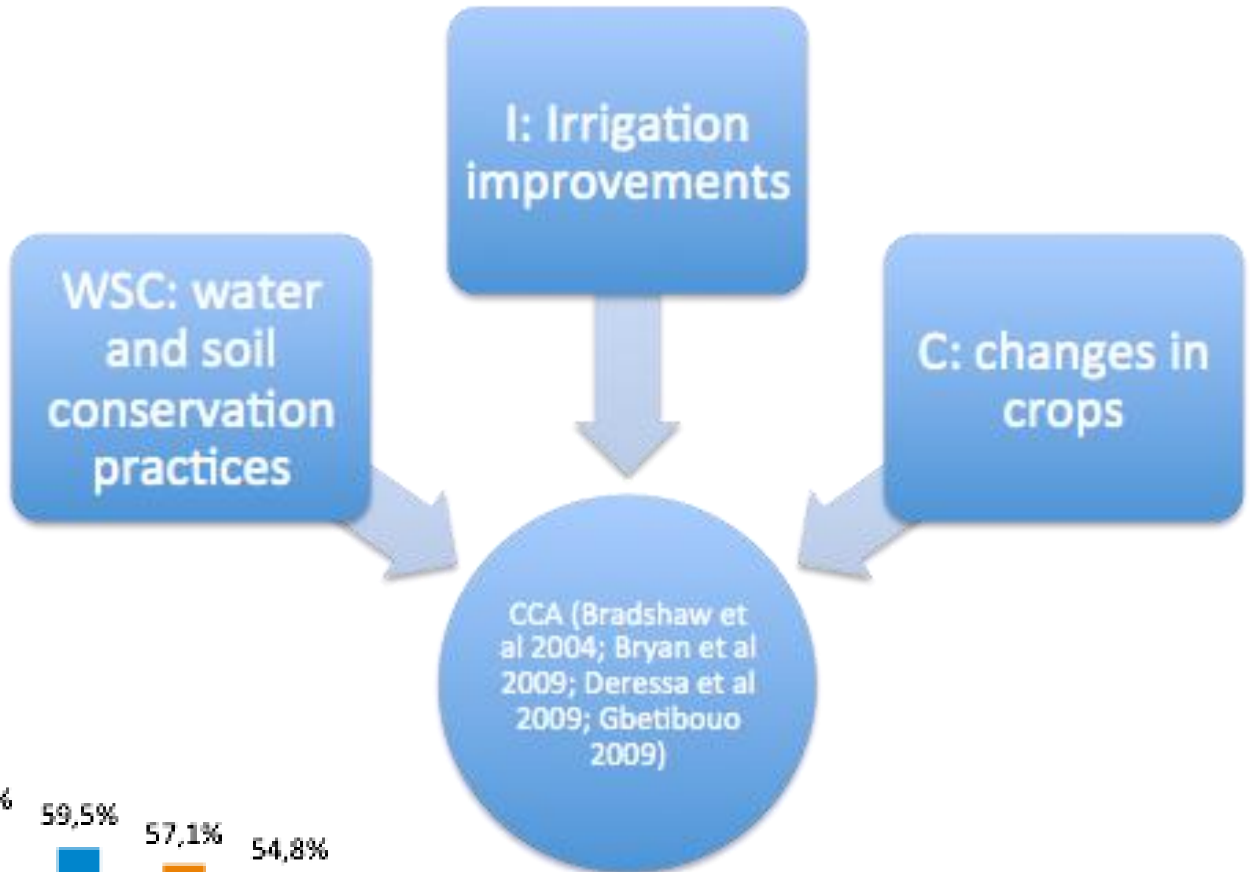
3. Data & Methods – Sample

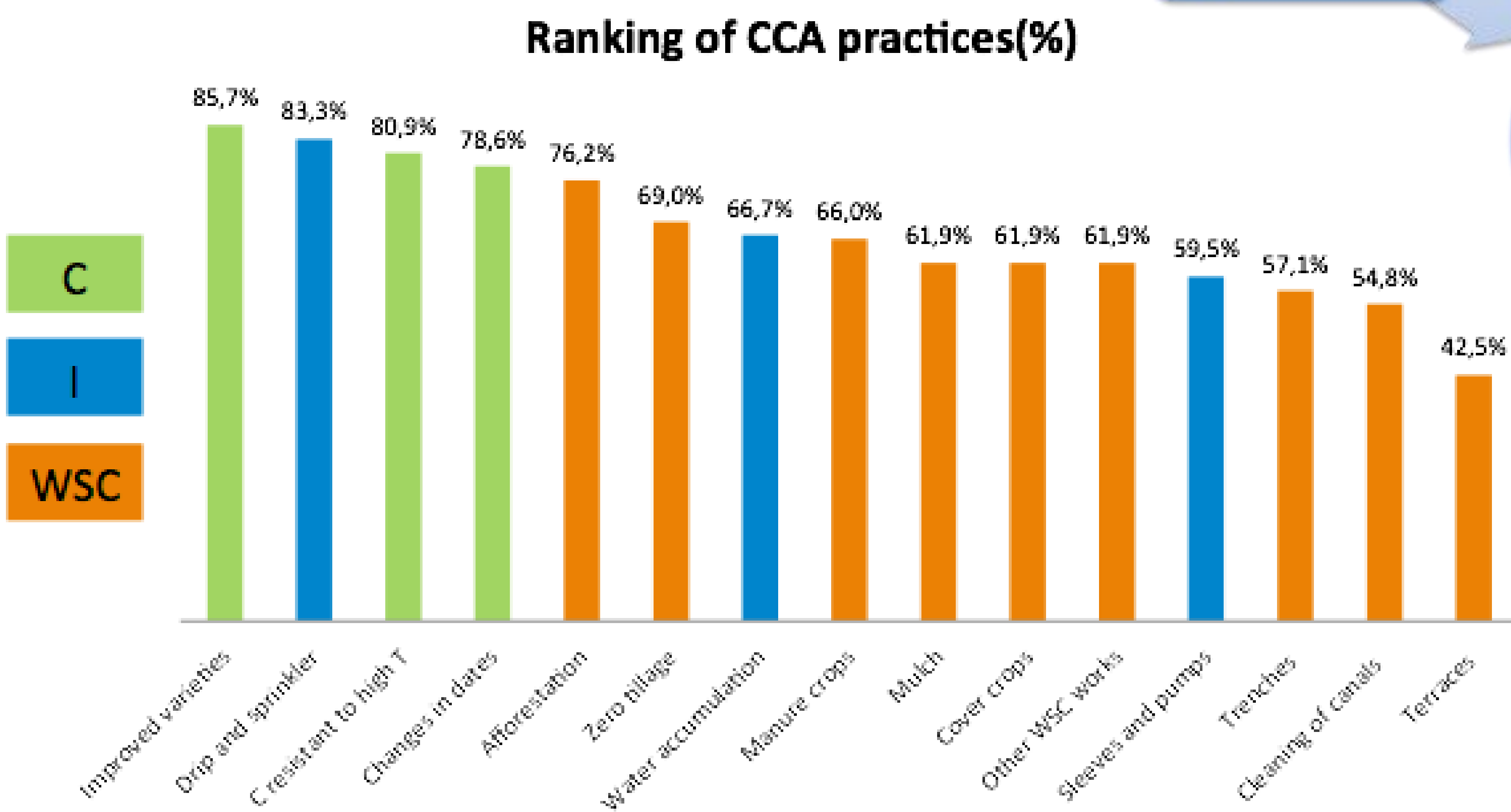
Municipality	Área	Rainfall (mm/year)	Farms	Farms Interviewed	Main crop system (%)				
					Wheat and oat	Spring crops[a]	Spring vegetables[b]	Rice	Others crops[c]
Pencahue	Irrigated interior dryland	709	1,129	40	12.5	35.0	52.5	0.0	0.0
Cauquenes	Non irrigated interior dryland	670	3,026	81	97.5	2.5	0.0	0.0	0.0
San Clemente	Irrigated andean foothill	920	2,990	89	40.4	42.6	12.4	0.0	4.6
Parral	Central valley	900	1,813	89	54.5	7.3	1.8	36.4	0.0
	Total		**8,958**	**265**	**56.6**	**77.4**	**12.5**	**7.5**	**1.5**

[a]: Spring crops are: maize, beans, and potatoes
[b]: Spring vegetables are: peas, onion, tomato, melon, watermelon, cucumber, and squash
[c]: Other crops are: tobacco and cabbage



3. Data & Methods – CCA: Experts' Opinion





3. Data & Methods – CCA: Experts v/s Field

Practice	Type[a]	Score %	Farmers (n = 265)	
			No. of respondents	% of Total
Incorporation of crop varieties resistant to droughts	Cr	85.7	2	0.7
Use of drip and sprinkler	I	83.3	31	11.7
Incorporation of crops resistant to high temperatures	Cr	80.9	2	0.7
Changes in planting and harvesting dates	Cr	78.6	110	41.5
Forestation on bare soil	WSC	76.2	5	1.9
Zero tillage	WSC	69.0	3	1.1
Use of water accumulation systems	I	66.7	38	14.3
Use of green manure	WSC	66.0	33	12.4
Use of mulching	WSC	61.9	24	9.0
Use of cover crops	WSC	61.9	16	6.0
Other WSC practices	WSC	61.9	16	6.0
Use of hoses and pumps for irrigation	I	59.5	52	19.6
Implementation of infiltration trenches	WSC	57.1	19	7.1
Cleaning of canals	WSC	54.8	60	22.6

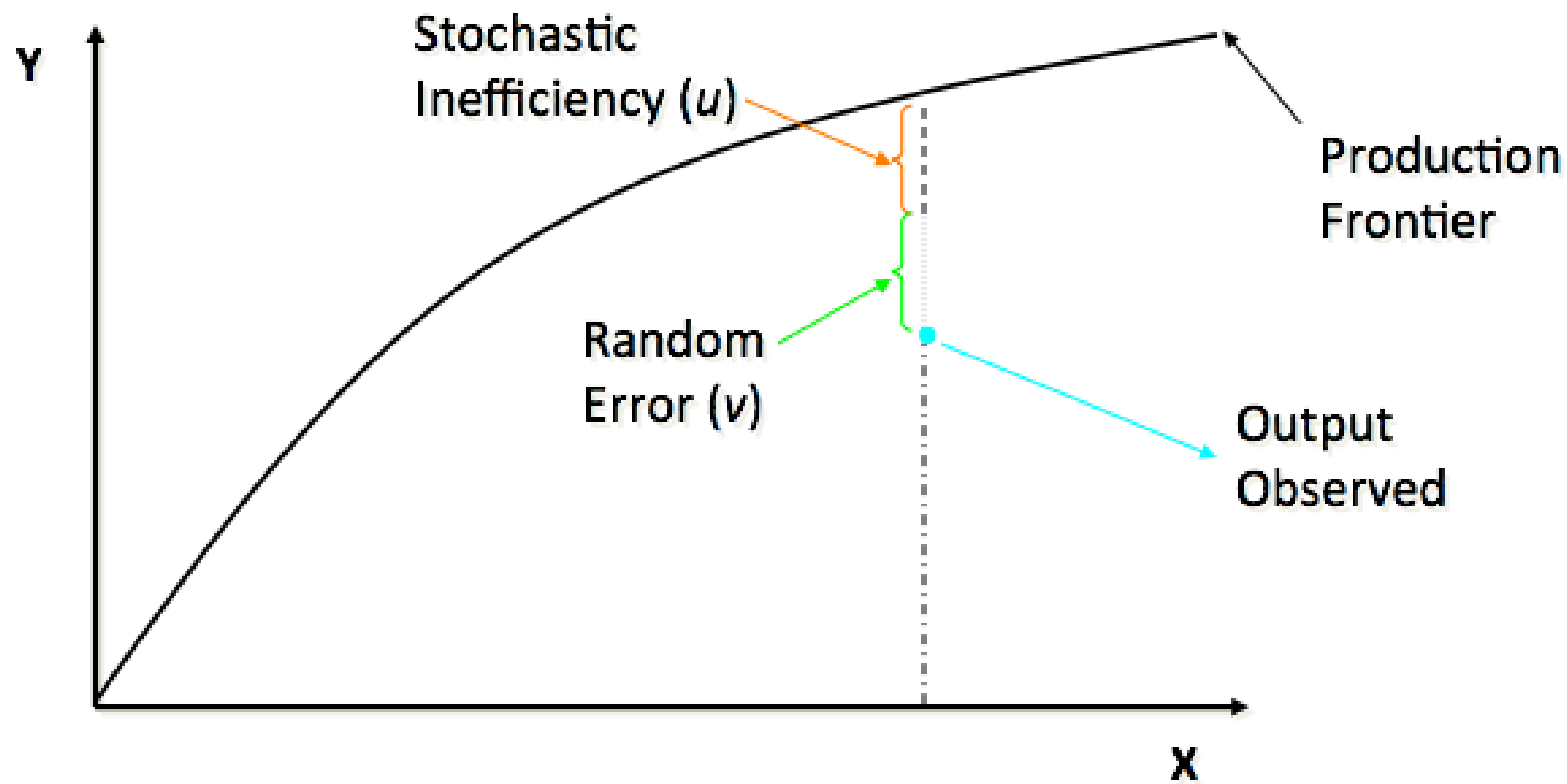
For details of CCA practices see: Roco et al. 2014. Farm level adaptation decisions to face climatic change and variability. *Environmental Science & Policy* 44: 86-96



3. Data & Methods – Production Frontier

- Aigner, Lovell and Schmidt (1977) y Meeusen and van den Broeck (1977)
- Battese and Coelli (1995)

$$Y_i = x_i\beta + (v_i - u_i)$$



3. Data & Methods - Cobb-Douglas

Cultivated Land

Capital

Labour

Dryland

Diversification

CCA

$$\ln y_i = \beta_0 + \beta_1 \ln L_i + \beta_2 \ln C_i + \beta_3 \ln W_i + \beta_4 D_i + \beta_5 H_i + \beta_6 A_i + (v_i - u_i)$$

Agricultural production

Random error

Error capturing TE

$$TE_i = \exp(-u_i)$$

$$u_j = \delta_0 + \sum_{n=1}^{k} \delta_n z_{nj} + e_j$$

Age
Schooling
Dependence
Specialization
Weather Information
Membership
Farm size
Distance to market

$$H = \left(1 - \sum_{i=1}^{n} \left(\frac{c_i}{T}\right)^2\right) * 100$$

TE: technical efficiency

3. Data & Methods - Considerations

To measure CCA:

1. Number of practices adopted (intensity)
2. Adaptation Index (Quality)
3. Binary variable (0/1)

The adaptation quality index (A2) was constructed considering the sum of the practices of a given farm multiplied by the scores assigned by the experts, divided by the sum of all the scores

$$A_{2_i} = \left[\frac{\sum_{j=1}^{14} Score_{ij}}{\sum_{j=1}^{14} Scorej}\right] * 100$$

Endogeneity:

- CCA is a variable that can present simultaneity with the production
- Test the presence of endogeneity (Durbin-Wu-Hausman test) and correct (Instrumental Variables)
- DWH test: the residuals of each endogenous variable on the right side are included as a function of all exogenous variables, in a regression of the original model (Davidson and MacKinnon, 1993)
- Regressions of instrumental variables:

1. Intensity: zero inflated negative binomial
2. Quality: linear truncated (0-100)
3. Decision: logit

4. Results – Production Function Variables

Variable	Name	Unit	Definition	Mean	SD
Production function variables					
y	Agricultural production	MMS	Crops production value in Chilean pesos[a]	31.2	14.0
L	Cultivated land	Ha	Hectares worked in crops	17.1	53.3
C	Capital	MMS	Value of seeds, fertilizers, pesticides purchased and machinery contracted in Chilean pesos	11.4	51.7
W	Labor	MMS	Value of the family and hired labor	2.2	6.8
D	Dryland	%	Dummy variable = 1 if the farm is located in dryland area and 0 otherwise	30.6	46.2
H	Diversification	%	Crop diversification index	23.7	27.5
A_1	Climate change adaptation	Discrete number	Number of climate change adaptation practices adopted in the farm (intensity)	1.8	2.2
A_2		%	Index of adaptation based on experts opinion (quality)	12.6	15.4
A_3		%	Dummy variable = 1 if there are at least one practice adopted and 0 otherwise (decision)	56.6	49.7
A_1'		Number	Estimation of A_1	1.7	0.7
A_2'		%	Estimation of A_2	17.0	8.0
A_3'		%	Estimation of A_3	56.6	13.8

[a] 470 Chilean pesos = US$1 for the study period

4. Results – Inefficiency Model Variables

Variable	Name	Unit	Definition	Mean	SD
Inefficiency model variables					
z_1	Age	Years	Age of the head of the farm in years	55.5	14.1
z_2	Schooling	Years	Years of schooling of the head of the farm	7.2	4.1
z_3	Dependence	%	Dummy variable = 1 if agriculture is the main source of income for the household and 0 otherwise	82.6	37.9
z_4	Specialization	%	Percent of total income that corresponds to income from crops	62.1	32.0
z_5	Use of meteorological information	%	Dummy variable =1 if the farmer is user of meteorological information and 0 otherwise	93.2	25.2
z_5	Membership	%	Dummy variable = 1 if the farmer is member of an association and 0 otherwise	52.4	50.0
z_7	Farm size	Ha	Total farm size in hectares	56.4	122.3
z_8	Distance to market	Km	Distance to regional capital city in kilometers	77.4	43.8

4. Results – Production Frontier Estimation

Variables	**Intensity**	**Quality**	**Decision**
Constant (β_0)	4.7996 (0.9253)***	4.7690 (0.9894)***	4.1356 (0.9463)***
Land (β_1)	0.2876 (0.0850)***	0.2726 (0.0877)***	0.2284 (0.0849)***
Capital (β_2)	0.5950 (0.0710)***	0.6041 (0.0779)***	0.6184 (0.0739)***
Labor (β_3)	0.1044 (0.0276)***	0.1140 (0.0275)***	0.1224 (0.0278)***
Dryland (β_4)	-0.4280 (0.1222)***	-0.3882 (0.1350)***	-0.3485 (0.1303)***
Diversification (β_5)	0.5933 (0.1373)***	0.6074 (0.1361)***	0.5670 (0.1312)***
Climate change adaptation (β_6)	0.1656 (0.0546)***	0.0075 (0.0052)*	0.1092 (0.3012)***
Returns to scale	0.9870	0.9907	0.9692
Inefficiency model			
Constant (δ_0)	0.3462 (0.6594)	-0.3082 (0.6554)***	0.2005 (0.6762)
Age (δ_1)	0.0171 (0.0080)**	0.0212 (0.0084)***	0.0124 (0.0083)*
Schooling (δ_2)	0.0147 (0.0270)	0.0107 (0.0296)	0.0200 (0.0175)
Dependence (δ_3)	-0.8436 (0.1797)***	-0.7310 (0.1800)***	-0.7099 (0.1738)***
Specialization (δ_4)	-0.0099 (0.0034)***	-0.0112 (0.0031)***	-0.0085 (0.0034)***
Use of meteorological information (δ_5)	-0.8279 (0.2463)***	-0.7480 (0.2556)***	-0.6258 (0.2770)**
Membership (δ_6)	0.2533 (0.1742)*	0.1915 (0.1884)	0.2027 (0.1698)
Farm size (δ_7)	-0.0028 (0.0029)	-0.0035 (0.0026)*	-0.0036 (0.0008)***
Distance to market (δ_8)	0.0038 (0.0031)*	0.0057 (0.0031)**	0.0085 (0.0033)***
TE	76.39	72.26	67.78
TE difference with models without considering endogeneity	***	***	ns

Numbers in parentheses are standard errors; *$p<0.1$; **$p<0.05$; ***$p<0.01$; ns: no significant; estimations using Frontier version 4.1 and STATA 11.1

4. Results – Efficiency Distribution

Interval TE	Farms in interval (%)					
	Non correcting endogeneity			Correcting endogeneity		
	Intensity	Quality	Decision	Intensity	Quality	Decision
0-29	3.0	3.0	2.6	2.6	3.4	6.4
30-39	5.3	5.3	9.1	3.0	4.5	7.9
40-49	6.8	6.4	7.2	4.9	6.0	6.4
50-59	6.4	6.4	10.6	6.0	6.4	9.1
60-69	13.3	13.7	16.6	9.4	12.1	10.9
70-79	23.0	23.0	25.6	16.7	23.4	22.7
80-89	35.8	34.7	23.8	45.7	35.9	30.6
>90	6.4	7.5	4.5	11.7	8.3	6.0
Average TE	71.3	71.5	67.5	76.4	72.3	67.8

Correlation matrix for TE values		Non correcting endogeneity			Correcting endogeneity		
		Intensity	Quality	Decision	Intensity	Quality	Decision
Non correcting endogeneity	Intensity	1.0000	-	-	-	-	-
	Quality	0.9999	1.0000	-	-	-	-
	Decision	0.9872	0.9876	1.0000	-	-	-
Correcting endogeneity	Intensity	0.9842	0.9841	0.9532	1.0000	-	-
	Quality	0.9967	0.9969	0.9874	0.9839	1.0000	-
	Decision	0.9779	0.9766	0.9666	0.9569	0.9741	1.0000

4. Results - TE Comparisons among groups

Average TE	Model	Grouping criteria: Adoption of at least one irrigation improvement			Changes in planting and harvesting schedules			Adoption of at least two adaptation practices			Value of adaptation index ≥ 25%		
		Yes	No	Sig	Yes	No	Sig	Yes	No	Sig	Yes	No	Sig
Complete sample	Intensity	80.9	74.4	***	75.1	77.3	ns	86.3	74.5	***	88.8	74.8	***
	Quality	77.5	69.9	***	70.9	73.3	ns	84.4	69.9	***	87.3	70.3	***
	Decision	73.5	65.3	***	64.9	70.0	**	81.4	65.1	***	86.5	65.4	***
	%	*54.7*			*42.6*			*16.2*			*11.3*		

*p<0.1; ** p<0.05; ***p<0.01, ns: no significant

5. Conclusions & Recommendations

- Great differences between the experts' recommendations and what happens in the field
- Major gaps in genetic improvement and irrigation
- Positive association between productivity and CCA in different specifications
- The endogeneity of the CCA is demonstrated in the fitted models
- The incorporation of instrumental variables allows to improve the estimates
- Adjusted models show significant levels of inefficiency, there is potential for increased crop production using current levels of inputs and available technology
- The dependence of agriculture on income and the degree of specialization of producers are associated with high levels of ET
- The use of meteorological information increases the levels of ET
- The farm size is positively related to efficiency, and the distance to the regional capital has a negative effect
- Irrigation improvements have an interesting effect on efficiency
- The CCA intensity is a key element for increasing efficiency among producers

5. Conclusions & Recommendations

- In relation to agricultural policy, our results demonstrate the importance of incorporating the CCA as an important factor for productive growth in a risky and environmentally dependent activity such as agriculture

- The connection between productivity and the implementation of specific adaptation practices, as well as actions to overcome the barriers to its implementation, are areas that deserve further analysis

- Following suggested steps:

  - Study the profitability of CCA strategies

  - Study differential responses to changes in rainfall and temperature regimes

  - Analyze how CCA-related program and investments have an effect on system vulnerability and resilience

  - Implement impact assessments of such programs

  - Incorporate permanent feedback into national CCA plans

Thanks for your attention!

Roco et al. 2017. The Impact of Climatic Change Adaptation on Agricultural Productivity in Central Chile: A Stochastic Production Frontier Approach. *Sustainability* 9: 1648.

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